

SAFETY IN INDUSTRY

**Mechanical and
Physical Hazards No. 6**

Bulletin No. 240

Rigging Cargo Gear



U.S. DEPARTMENT OF LABOR

Arthur J. Goldberg, Secretary

BUREAU OF LABOR STANDARDS

Arthur W. Motley, Director

PUBLICATIONS IN THE SAFETY IN INDUSTRY SERIES

MECHANICAL AND PHYSICAL HAZARDS SERIES

- Bulletin 216: Control of Electrical Shock Hazards. 1960. 15 pp. 15 cents.
- Bulletin 219: Mechanical Handling of Materials. 1960. 29 pp. 15 cents.
- Bulletin 231: Personal Protective Equipment. 1961. 26 pp. 15 cents.
- Bulletin 232: Fire Protection for the Safety Man. 1961. 25 pp. 15 cents.
- Bulletin 239: Mechanics for the Safety Man. 1962. 24 pp. 15 cents.
- Bulletin 240: Rigging Cargo Gear. 1962. 23 pp. 15 cents.

ENVIRONMENTAL AND CHEMICAL HAZARDS SERIES

- Bulletin 207: Controlling Noise Hazards. 1959. 8 pp. 10 cents.
- Bulletin 222: Chemistry for the Safety Man. 1960. 26 pp. 15 cents.
- Bulletin 226: Respiratory Protective Equipment. 1961. 34 pp. 20 cents.
- Bulletin 241: Chlorine Handling in Stevedoring Operations. 1962. 9 pp. 15 cents.

ORGANIZATION AND ADMINISTRATION SERIES

- Bulletin 211: Control of the Physical Environment. 1960. 13 pp. 15 cents.
- Bulletin 223: The Consultative Approach to Safety. 1960. 9 pp. 15 cents.

This bulletin, one of the series on Safety in Industry, was prepared by Ralph W. Netterstrom, Chief, Maritime Branch, Division of Safety, under the general direction of Robert D. Gidel, Assistant Director, Bureau of Labor Standards. Adaptation to bulletin format was provided by the Technical Branch.

CONTENTS

	Page
The Swinging Boom.....	2
Stress at High Angles.....	4
Boom Failures.....	5
Gooseneck Failures.....	6
Guy Failures.....	6
Auxiliary Stays.....	7
Conclusion.....	7
Burtoned Loads.....	7
Tension on the Falls.....	8
Stress On Guys.....	10
Boom Angled Inboard From Heel.....	12
Boom Fore and Aft From Heel.....	14
Boom Angled Outboard From Heel.....	17
Burton Boom.....	17
Jackknifing.....	17
Jackknifing the Burton Boom.....	19
Ebel Gear.....	20
Preventers.....	20
Summary of Suggested Safe Practices in Rigging and Using Cargo Handling Gear.....	21

Safety in Industry

MECHANICAL AND PHYSICAL HAZARDS

RIGGING CARGO GEAR

THIS bulletin, "Rigging Cargo Gear," differs from others in the Safety in Industry series in that it is written for and about a specific industry—stevedoring. Since this is the case, the terminology of the industry, which may or may not be familiar to some of the people acquainted with other bulletins in the series, has been used. Also, a much more informal and personalized style of presentation has been adopted.

"Rigging Cargo Gear" was first published in mimeograph form in 1953. Over the years it has been revised and extended to reflect the Bureau of Labor Standards' efforts to prevent injuries in the use of ship's gear, first on a promotional and educational basis, and later under the administrative authority contained in Public Law 85-742 amending the Longshoremen's and Harbor Workers' Compensation Act. Although the bulletin is based on equipment peculiar to the maritime industry, it is believed that the suggestions offered can, in some cases, be applied to shore based hoisting apparatus as well.



Failure of conventional ship's cargo gear, while not common, occurs more frequently than necessary. Claims for gear replacement, cargo damage, loss of time and occasional injuries to personnel are the costs which the stevedore must often pay for the failure of gear which he does not own and over which he does not have complete control.

The fundamental cause of gear failure in burtoning cargo is the lack of safety devices to prevent overloading the gear and the lack of information available to the stevedore or the ship operator as to when gear is being overloaded.

Experienced seamen and stevedores know that if the falls are tightlined with little or no load on the hook, all but the weakest winches will part a guy or tear down a boom. They also know that if a load close to the alleged "5 ton SWL" of a set of gear is burtoned,

the gear seems to be under excessive stress and may fail. The reason for these failures is seldom understood.

It is the purpose of this bulletin to give an understanding of the stresses to which the gear is subjected, to present a few simple rules for rigging the gear to keep these stresses at a minimum, and to point out in a general way the practices and conditions which are likely to result in failures. The illustrations used are based on the dimensions of a single specific set of gear. For other gear and other setups of the same gear, the stresses will differ from those indicated, but, except in very unusual cases, not to a significant degree. In any case the principles involved apply to all gear used for burtoning. If the stevedore combines this information with his own experienced judgment of the condition of the particular gear which he happens to be working, he can prevent many gear failures and so obtain a safer and more efficient operation.

The attempt has been made to present the explanatory material in as simple terms as possible, taking the development step by step. If a single model boom is erected, using approximately the proportions given in the examples, the statements regarding tension on lines can be demonstrated with a small spring scale and some fishline and sinkers.

The conclusions and practical applications of each step are summarized in the back of the bulletin.

THE SWINGING BOOM

Failures of swinging booms from overloading are rare because their safe working loads can be stated clearly and the safety factor is relatively high. The stresses on a swinging boom will be considered, however, because a knowledge of them will aid in understanding the additional stresses that are set up by burtoning cargo.

Figure 1A shows the compression on the boom and the tension on the topping lift produced by a 1-ton load hanging from the head of the boom. (The compression on the boom produced by the tension of the fall between the head block and the heel block has been disregarded. With a single part fall, it is equal to the weight of the load.) The boom is 55 feet long and is supported by a mast that is 43 feet between the heel of the boom and the topping lift block. The boom is shown in three different positions, from horizontal to about as high an angle as is likely to be worked. (See Plate 1.)

At 75° elevation of the boom, the tension on the topping lift is only 0.4 ton while, when the boom is horizontal, the tension on the topping lift is 1.6 tons. This increase is easy to understand if one realizes that, if the boom were standing upright, all the weight would be on the heel, and a man upon the mast could keep it from falling with his hand.

PLATE I.—Stresses on swinging boom at various boom angles.

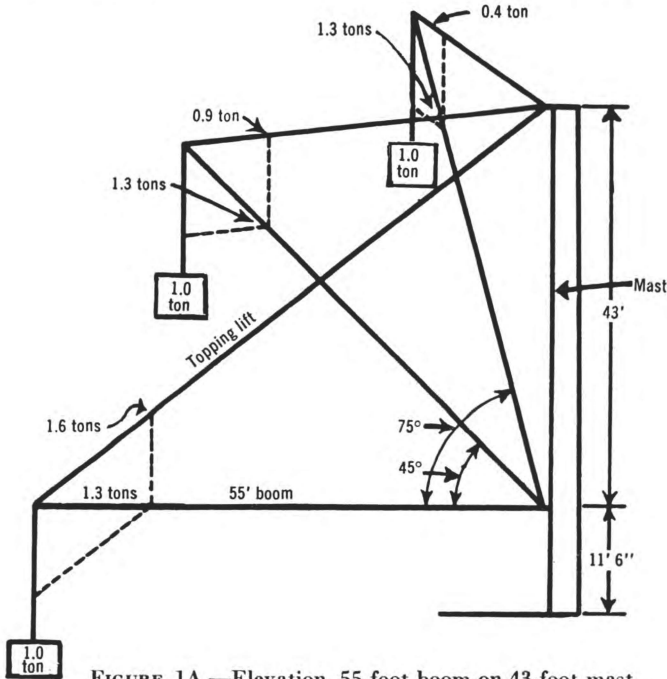


FIGURE 1A.—Elevation, 55-foot boom on 43-foot mast.

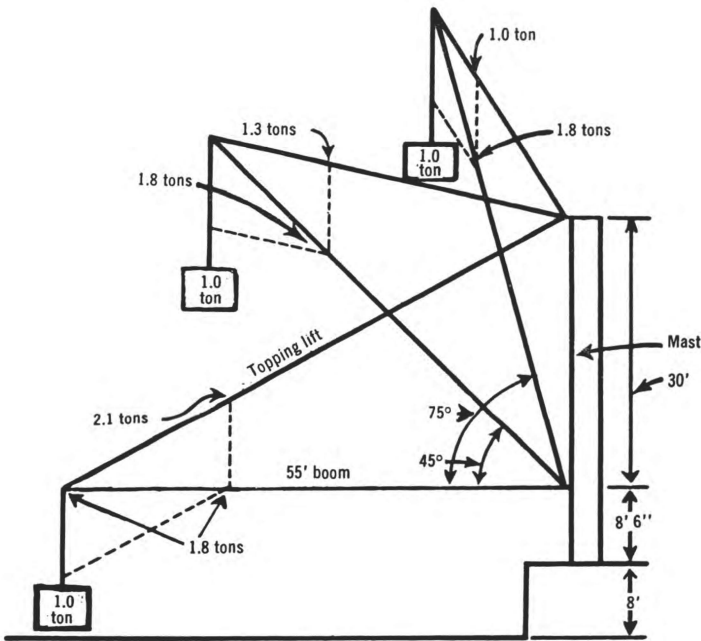


FIGURE 1B.—Elevation, 55-foot boom on 30-foot mast.

When the boom is horizontal, however, it is supporting none of the load, which is held entirely by the topping lift. The boom now serves only to force the load and the topping lift away from the mast.

The weight of the boom itself acts in a similar manner. In a vertical position this weight is all on the heel but when the boom is horizontal, half the weight is on the heel and the other half is supported by the topping lift.

Failure to realize that the tension on the topping lift increases as the boom is lowered has caused many booms to be dropped. The longshoreman takes enough turns on a cleat or gypsy to hold the boom when it is high, but when the tension gradually increases to the point at which he realizes that he needs another turn, he can't hold the line with one hand while he takes it. Then he must let go and the boom drops. On the other hand a boom is rarely dropped while raising it as the man must have sufficient turns to pick it up.

Figure 1B shows the stresses produced by a 1-ton load on the same length boom but on a shorter mast—30 feet from heel to topping lift block. The same three angles of the boom have been taken. At each angle the tension on the topping lift is greater than it was for the longer mast, going from 1 ton at 75° to 2.1 tons when the boom is horizontal.

This difference in tension on the topping lift for the two heights of mast is caused by the difference in the angle between the topping lift and the boom in the two cases. The smaller this angle, for the same angle of the boom, the greater the tension on the topping lift will have to be. (This can easily be demonstrated by raising the cover on a manhole. Your arm is the topping lift. If you pull always at right angles to the cover, it comes easily. But try raising it with your arm just a few inches above the hinge.) As might be expected, an increase in the tension on the topping lift produces an increase in the compression on the boom. In Figure 1A the compression is 1.3 tons, while in Figure 1B it has gone up to 1.8 tons.

This relationship between height of mast and length of boom is of no importance on a jumbo because it is taken into account in designing the gear. On light gear, however, it may be overlooked and the same strength, 55-foot boom, for example, may be used on a short mast as on a tall one. Since the difference in compression on the boom applies just as well to burtoning as it does to handling a load on a swinging boom, it is suggested that when he has a choice, the stevedore handle heavier loads, such as lift trucks, on the set of gear with the taller mast or king post.

Stress at High Angles

If the mast were the same height as the length of the boom, the tension on the topping lift would continue to decrease as the boom was

topped higher than the 75° shown in the illustrations and would become zero when the boom was vertical.

Since in almost every set of gear the mast is shorter than the boom, a point is reached in topping the boom beyond which no further reduction in tension on the topping lift occurs. For example, with the proportions shown in Figure 1A, the tension on the topping lift will decrease to about one-quarter the weight of the load at more than 85° but with the proportions shown in Figure 1B the tension on the topping lift will remain approximately equal to the weight of the load at angles above 75° while the compression on the boom will increase slightly.

There is also a slight increase in topping lift tension and boom compression at high angles caused by the fact that these two lines do not meet the boom at a point, as shown in the drawings, but are offset from the axis of the boom by the head fittings. The result is the same as lengthening the boom. These increases are small and of no importance in practical operations.

Boom Failures

Since it is general knowledge that there is more danger of boom failure when the boom is low than when it is topped well up, the figures indicating that the compression on the boom remains the same at all angles may seem in error. The fact is that a boom fails, not through collapsing like an accordion but by bending like a soda straw. As long as the straw remains perfectly straight it can support a considerable weight, but once it starts to bend very little weight will cause it to fold up completely. What happens to the soda straw happens also to the boom.

When the boom is topped well up, its own weight is pretty much in line with its axis. Just as a man with his arms extended above his head can brace himself against the wall with his finger tips and keep his body straight, the boom easily remains straight. If, however, the average man tries to support himself with his toes on one chair and his extended arms reaching another, he will sag in the middle. The boom laid flat and supported by the gooseneck at one end and the topping lift at the other tends, like the man, to sag in the middle.

The boom has a greater tendency to fail at a low angle, not because there is greater compression on it but because it is less able to withstand the same compression when it is slightly bent by its own weight.

These principles apply equally well to both burtoning and to the use of the swinging boom. Three practical applications of the above facts can be made.

1. Particular care should be taken to avoid overloading or putting shock loads on the gear when the boom is at a low angle.

2. Care should be taken to avoid letting a loaded boom come up against a stay, shroud, or other fixed object, as the resultant bending may cause the boom to fail.

3. While it would be difficult, if not impossible, to judge from appearance just how much a boom was weakened by one or two inches of permanent set, there is no doubt that its strength is reduced. It is suggested that the stevedore inspect all booms before starting work and report any bent booms to the mate.

Gooseneck Failures

Failures of the jumbo gear are usually confined to breaking the gooseneck of pacific iron. The most obvious cause is heaving on the guys with power when the gooseneck is frozen through lack of lubrication. It is suggested that stevedores try to have the ship's crew break out the jumbo and see that it is swinging freely before the longshoremen touch it. If the stevedore must break out the boom it should be lowered to an angle of about 45° , keeping the guy on the high side taut if there is a list on the vessel. Then have a few men swing on a guy to be sure that the gooseneck is free. If it will not turn by hand, additional effort should be made at the gooseneck rather than by heaving on the guy with winch power. Power applied to the end of a 50-foot wrench handle (the boom) is certainly going to move something but it may not break loose the rusted pin.

Another cause of bending or breaking the pacific iron is attempting to slew the boom with the guys when the boom is topped high. A moment's thought will show that if the boom is straight up and down, it must rotate to turn the gooseneck. Pulling on a guy would only bend the pacific iron—not rotate the boom. To be sure, neither the jumbo nor any other boom is worked in a vertical position, but at high angles the head of the boom goes through a very small arc as the gooseneck turns. In such a position more of the pull on the guy tends to bend the pacific iron than tends to turn the gooseneck.

For this reason it is suggested that the boom be topped no higher than necessary for the load to clear the deck before it is swung into its athwartships position. It can then be topped as high as necessary. In discharging cargo from the near end of the hatch, the boom should be lowered before it is swung.

Guy Failures

The guys on jumbo booms have carried away because the two drivers of the guy winches did not act together. One heaved while the other held or both heaved together. This can be avoided by being sure that both men can see the signalman. As a further precaution, winch drivers should be instructed to stop heaving and hold if at any time the stress on the guy appears to be excessive. It is difficult to imagine

a situation in which to stop heaving would introduce a hazard. To stop in case of doubt might disclose a misunderstanding of signals in time to avoid carrying away a guy.

Auxiliary Stays

Some vessels, notably the Liberty ships, require setting up auxiliary stays on the mast when the jumbo is used. Failure to observe this precaution, which is clearly stated on the rigging plans, has resulted in carrying away some masts.

Conclusion

By observing the safe working loads for which the booms are rated and the precautions noted above, the possibility of failure of gear when using a swinging boom is very slight if proper inspection and maintenance schedules are followed.

BURTONED LOADS

The stresses on the gear when the boom is used swinging are relatively simple. Overstressing any part of the gear far beyond the designed limits can be avoided merely by keeping the loads within the rated capacity. In burtoning, however, no simple load limitation can be fixed. The stresses produced by a given weight of load vary widely with differences in the trimming of the booms, the position of the guys and the height to which the load is raised.

We shall start the discussion of these factors with the last point and consider the effect of the height of the load on the tension in the falls.

Keeping in mind that the actual downward pull of the load is only 10 pounds on each end of the line, what happens to all this extra pull? If you look closely at the figures you will see (and if you try the experiment you will feel) that it is largely a horizontal pull. Exactly the same thing takes place when a load is supported between the heads of the two booms. This horizontal pull tends to move the heads of the booms together. The outboard or working guys hold the booms against this pull.

Table I lists the tension on the fall and the horizontal pull tending to move the heads of the booms together for a load of a 2,000-pound ton at various angles between the falls. When loads are tightlined as high as the winch can lift them, the tension on the falls is limited only by the strength of one winch. With a heavy load the final fall angle will be small. With a light load it will be large. The interesting thing is that the light load at the large fall angle will produce a greater horizontal force than will the heavier load which stalls the

winch at a smaller fall angle. It is this horizontal pull that the guys have to counteract.

TABLE I

Fall angle	Angle of each fall with horizon	Ratio of tension on fall to weight of load	Tension on each fall with load of 2,000 pounds	Horizontal pull tending to bring boom heads together
0°	90°	.50	(Pounds) 1,000	(Pounds) 0
60°	60°	.57	1,155	577
90°	45°	.71	1,414	1,000
120°	30°	1.00	2,000	1,732
140°	20°	1.46	2,924	2,748
150°	15°	1.93	3,864	3,732
160°	10°	2.88	5,759	5,671
170°	5°	5.74	11,474	11,430
175°	2.5°	11.46	22,926	22,904

The above values for the tension on the fall are most frequently seen in tables and diagrams of sling angles. The only difference is that the sling angle diagram is upside down when applied to fall angles.

These facts have the following practical applications in burtoning:

1. Use slings which are no longer than necessary.
2. Keep the hook as close to the junction of the falls as possible.¹ If chain is used for additional weight, hang it in a bight beside the hook rather than between the hook and the junction of the falls.
3. Keep the loads as close to the rail as is practicable.

Tension on the Falls

The tension on the falls increases as the angle between them increases. Suppose we tie one end of a line to a pad eye on the bulkhead, hang a block with a 20-pound weight in the bight, attach the other end of the line to a scale, and then hold the scale. If we hold the scale close to the padeye, as in Figure 2A, it will read one-half the weight of the load, or 10 pounds. We support one-half the weight and the pad eye supports the other half. As we move back from the bulkhead, the reading on the scale will gradually increase. When the angle between the two parts of the line is 90° (Figure 2B), the scale will read 14 pounds. When the angle in the bight is 120°, the scale will read 20 pounds (Figure 2C), or the weight of the load. (See Plate II.)

From this point on a small change in the angle between the lines will produce an increasingly large change in the scale reading as shown in succeeding figures. At 140° (Figure 2D), the stress is

¹ Sec. 9.52(f) of the Safety and Health Regulations for Longshoring limits this distance to 2 feet.

PLATE II.—Tension on the falls depends upon angle between the falls.

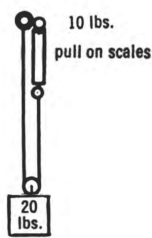


FIGURE 2A.—Fall angle 0°.

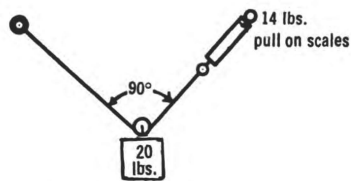


FIGURE 2B.—Fall angle 90°.

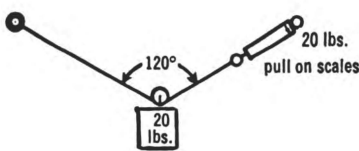


FIGURE 2C.—Fall angle 120°.

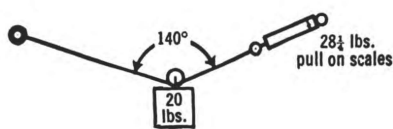


FIGURE 2D.—Fall angle 140°.

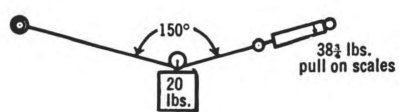


FIGURE 2E.—Fall angle 150°.

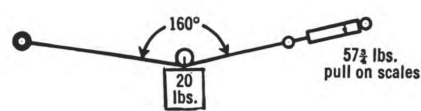


FIGURE 2F.—Fall angle 160°.

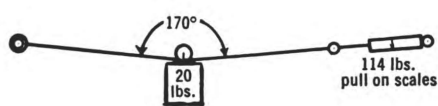


FIGURE 2G.—Fall angle 170°.

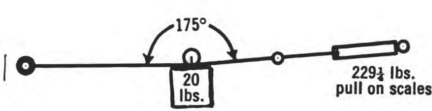


FIGURE 2H.—Fall angle 175°.

almost one and one-half times the weight of the load, and at 150° (Figure 2E) is almost double. At 160° (Figure 2F), the stress in the line is nearly 3 times the weight of the load, and to get the angle to 170° (Figure 2G) will require a pull of $5\frac{3}{4}$ times the weight of the load. If we wish to flatten the angle out to 175° (Figure 2H), we will have to pull $229\frac{1}{4}$ pounds or $11\frac{1}{2}$ times the weight of the load to do so.

4. Severe tightlining of even very light loads is dangerous because a difference of only a foot or two in the height of the load may increase the stress tremendously.

STRESS ON GUYS

Experience shows that the burton (yard) gear very seldom presents any difficulty. When failures occur they are confined almost entirely to the up-and-down (midships) gear. For this reason the following discussion of stresses in relation to trimming the boom and guy refers exclusively to this side of the rig with only brief mention of the burton gear.

Figure 3A shows a plan view of a typical set of gear (No. 4 aft on a C-3) trimmed to work the near end of the hatch with the up-and-down boom in a fore and aft line through its heel and the guy in line with the fall. A number of elevation views are shown with calculations to indicate the tension on the guy produced by a one-ton load at several different fall angles. In these and the following illustrations the actual compression on the boom is not shown. Instead, the figure on the boom indicates the weight of load which, when lifted on a swinging boom, would produce approximately the same compression in the boom as is produced by the one-ton load in the situation shown. (The tension of the fall along the boom from head block to heel block has been disregarded. See Plate III.)

It will be noted (Figure 3B) that even with a fall angle of only 90° , where the junction of the falls is about 20 feet above the deck, the tension on the guy is 1.6 tons and the boom has to support the equivalent of 2.1 tons. The stresses go up (Figures 3C and 3D) as the one-ton load on the hook is raised until, (Figure 3E) the angle between the falls reaches 150° , when the tension on the guy is 6.2 tons and the equivalent load on the boom is 6.4 tons.

This explains why a boom which has been tested with a swinging load of 7 tons will sometimes fail under a load of only 3 or 4 tons which is being supported by 2 booms. Unless otherwise stated, "5 ton SWL" stenciled on the heel of a boom refers to a load on a swinging boom, not to a burtoned load.

PLATE III.—Tension on guy and equivalent load on swinging boom for various fall angles. Boom fore and aft. Guy in line with fall.

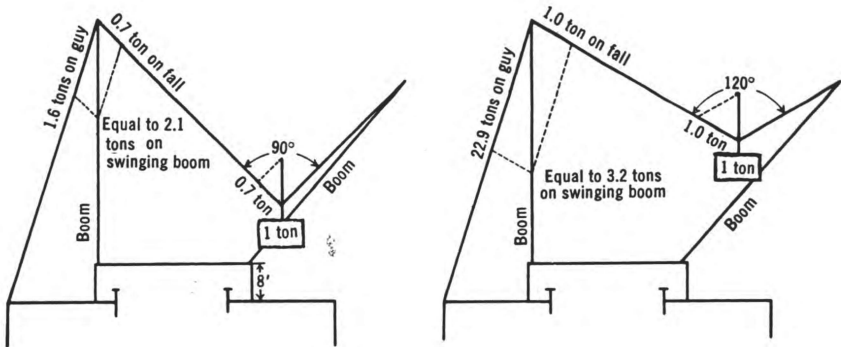


FIGURE 3B.—Stresses at fall angle of 90°. FIGURE 3C.—Stresses at fall angle of 120°.

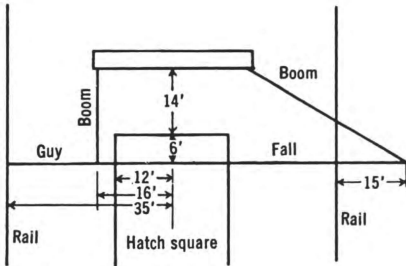


FIGURE 3A.—Plan stresses on gear, 55-foot boom fore and aft. Guy in line with fall.

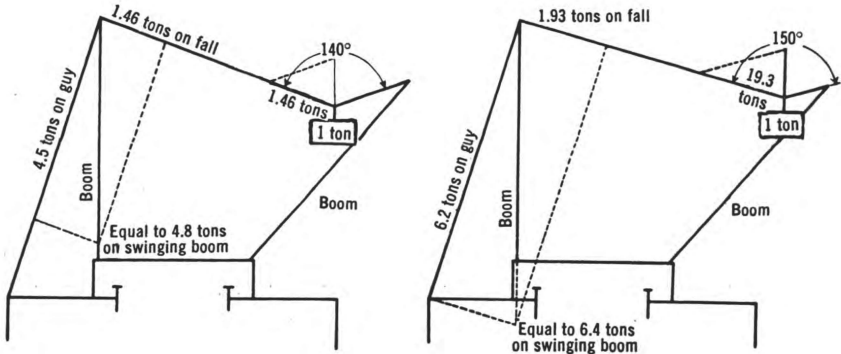


FIGURE 3D.—Stresses at fall angle of 140°. FIGURE 3E.—Stresses at fall angle of 150°

Boom Angled Inboard From Heel

Merely by swinging the boom inboard to the center line of the vessel (and slacking off on the topping lift so that the head of the boom is still the same distance from the end of the hatch, Figure 4A), we find that the stresses are considerably reduced. At a fall angle of 90° (Figure 4B), the tension on the guy has dropped from 1.6 tons to 1.0 ton and the equivalent load on the boom from 2.1 to 1.3 tons. At a fall angle of 120° (Figure 4C), the guy tension drops from 2.9 tons to 1.7 tons and the equivalent load on the boom from 3.2 to 1.9 tons. (Since the values for other fall angles are reduced in proportion, they are not shown. See Plate IV.)

Since the fall angles and therefore the horizontal pull are the same, one may wonder why the tension on the guy is lower in Figure 4C than in Figure 3C. A comparison of the two figures will show that the guy in Figure 3C is much more nearly vertical than it is in Figure 4C. Since the guy serves only to keep the head of the boom from moving horizontally, it could do this most easily if it too were horizontal. (You pull straight out on a door handle, not down toward the floor.) On the other hand, it should be clear that pulling straight down on the guy would do nothing to keep the boom head from swinging around. Therefore, the further the guy is from the vertical, the less tension on it, and the more nearly it approaches the vertical, the greater the tension on it.

One other benefit of swinging the boom inboard should be pointed out. In Figure 3B the fall angle of 90° was reached with the junction of the falls 20 feet above the deck, while in Figure 4B this angle was not reached until the junction of the falls was 26 feet above the deck. In other words if, with the setup shown in Figure 4B, we kept the load only 20 feet above the deck, we should have had a smaller fall angle and hence even less tension on the guy.

Now let us leave the boom where it is but move the guy around to see whether any further reduction in tension can be obtained. Looking at the plan shown in Figure 5B, we see that the head of the boom is not going to move directly athwartships in line with the fall but is going to swing in an arc around the mast or king post along the path of the curved arrow. The guy can most easily prevent this swing if it is at right angles to the boom. (Remember that you keep your arm at right angles to the door when opening a heavy one.) With the guy in line with the fall, Figure 5B, the horizontal pull acting on the guy must be the same as that produced by the fall. For a fall angle of 120° , this is equal to .86 times the weight of the load as shown in Figure 5A. Using this value in Figure 5C, we find that the horizontal pull on the guy when it is at right angles to the boom has been reduced to .70 times the weight of the load. In Figures 5D and 5E are shown the guys in the two respective positions as they

PLATE IV.—Tension on guy and equivalent load on swinging boom at various fall angles. Boom over center line. Guy in line with fall.

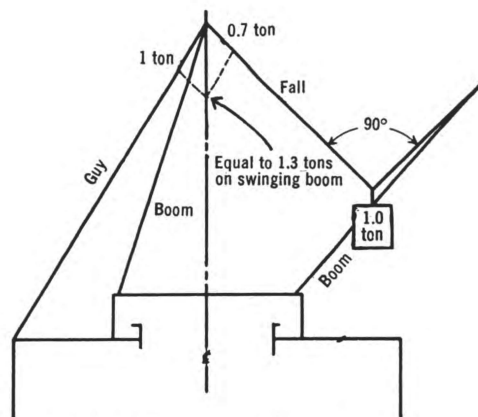


FIGURE 4B.—Elevation, stresses at fall angle of 90° .

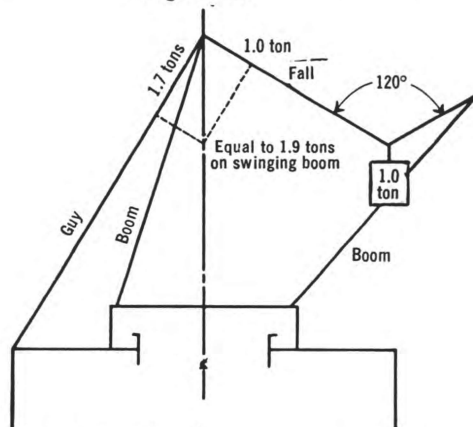


FIGURE 4C.—Elevation, stresses at fall angle of 120° .

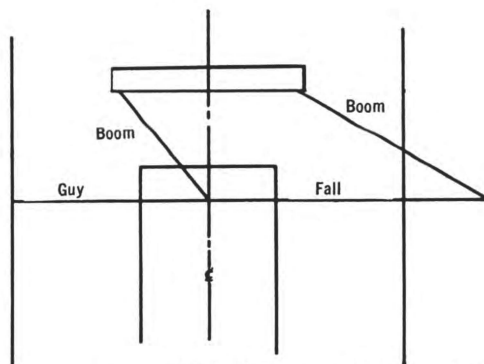


FIGURE 4A.—Plan, stresses on gear. 55-foot boom angled inboard from heel. Guy in line with fall.

would appear at their true length. The .86-ton horizontal pull produces an actual tension of 1.7 tons in the guy in line with the fall (the same value which was reached by a different method in Figure 4C) and the .70-ton horizontal pull produces an actual tension of only 1.1 tons on the guy at right angles. In the latter position, the tension on the guy is reduced not only by a decrease in the horizontal pull but also by the fact that the guy is flatter and hence can hold the boom more easily. The equivalent load on the boom is 1.5 tons as compared with 1.9 tons when the guy is in line with the fall. (See Plate V.)

Theoretically we could move the guy even beyond a right angle to the boom and have some further slight reduction because the guy would become still flatter. From a practical standpoint however, the movement of the guy in this direction is either limited by the shrouds at the next set of gear or, when the boom is not angled so far inboard, might be carried too far.

The practical application of these facts is as follows:

1. The closer the heads of the two booms are together, and the higher they are, the less will be the tension on the falls and therefore on the guys for any given height of the junction of the falls.

2. When the boom angles inboard from its heel, the tension on the guy will be least when the guy is approximately at right angles to the boom in plan view, or as seen when looking up from on deck.

Boom Fore and Aft From Heel

Referring back to Figure 3C, we saw that with the boom fore and aft, and the guy in line with the fall, a one-ton load at a fall angle of 120° produced a tension of 2.9 tons on the guy. If we move the guy back abreast the heel, as in Figure 6A, we will find (Figure 6B) that the tension on the guy has increased to 3.0 tons but the equivalent load on the boom has decreased from 3.2 tons to 2.9 tons. If, however, we lead the guy out ahead of the boom, as in Figure 6C, the same distance that it was behind the head in Figure 6A, the tension on the guy is not changed (Figure 6D). It remains at 3.0 tons but the equivalent load on the boom will increase from 2.9 tons to 3.6 tons. (See Plate VI.)

This increase in load on the boom when the guy is out ahead of the boom is caused by an increased tension on the topping lift, which went up from 0.5 to 2.8 tons. The guy pulls against the topping lift. When, however, the guy is abreast the heel, it pulls more nearly in the same direction as the topping lift and actually takes some of the load from it. (An extreme example of this occurs when the guy is so far behind the heel that it causes the boom to jackknife. There is then no load on the topping lift at all.)

The application of these facts is as follows:

With the boom fore and aft, the least compression will be placed on the boom if the guy is back near the heel. The least tension on the

PLATE V.—Showing change in tension on guy and equivalent load on swinging boom with change in position of guy. Boom over center line. Fall angle of 120° .

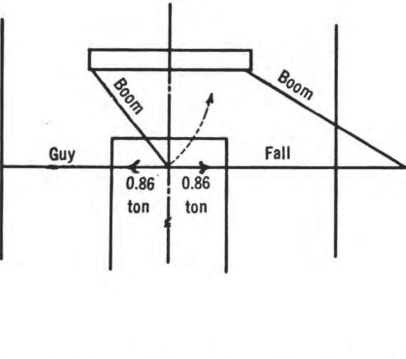


FIGURE 5B.—Plan, horizontal pull on fall and guy. Guy in line with fall.

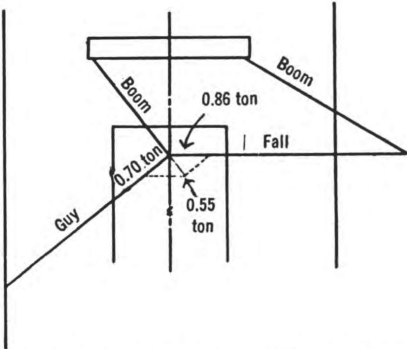


FIGURE 5C.—Plan, horizontal pull on fall and guy. Guy at right angle to boom.

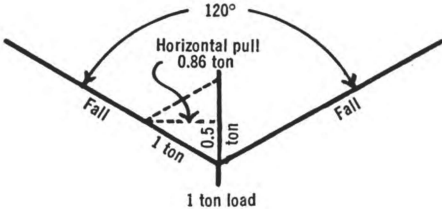


FIGURE 5A.—Elevation, junction of falls showing tension on falls and horizontal pull on falls at angle of 120° .

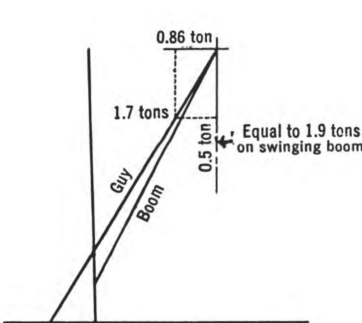


FIGURE 5D.—Guy and boom from 5B in true length showing tension on guy and equivalent load on swinging boom.

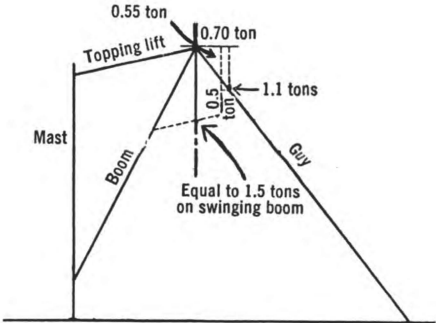


FIGURE 5E.—Guy and boom from 5C in true length showing tension on guy and equivalent load on swinging boom.

PLATE VI.—Showing changes in tension on guy and equivalent load on swinging boom with changes in position of guy. Boom fore and aft. Fall angle 120° .

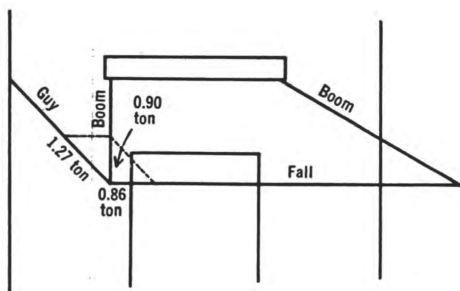


FIGURE 6A.—Plan, horizontal pull on guy and horizontal thrust on boom. Guy abreast heel. Fall angle 120° .

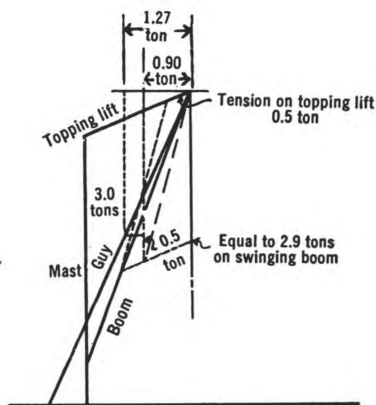


FIGURE 6B.—Guy and boom from 6A in true length showing tension on guy and topping lift and equivalent load on swinging boom.

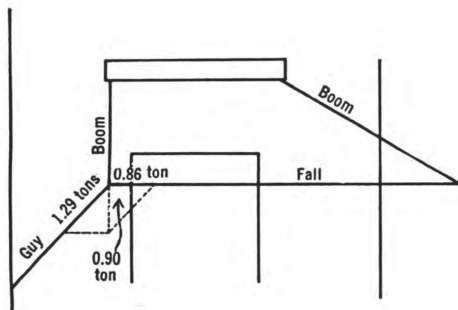


FIGURE 6C.—Plan, horizontal pull on guy and horizontal thrust on boom. Guy ahead of fall. Fall angle 120° .

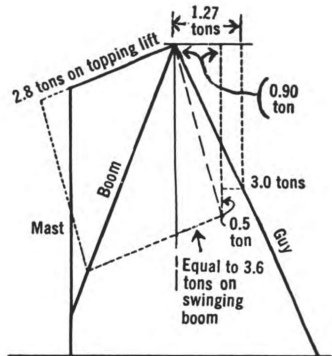


FIGURE 6D.—Guy and boom from 6C in true length showing tension on guy and topping lift and equivalent load on swinging boom.

guy will result if it is at right angles to the boom. With light booms on short masts, place the guy near the heel. With heavy booms and light guys, place the guy at right angles to the boom.

Boom Angled Outboard From Heel

In working an offshore deckload, or in spotting a boom over the offshore coaming, the boom on most gear will angle outboard. In such a case, it is very important that the guy be led back abreast the heel to avoid excessive stress. Figure 7 illustrates such a situation and shows three possible guy locations. At A, it is in line with the fall; at B, it is abreast the heel; and at C, it is about as far back of the heel as it can be placed without allowing the boom to jackknife. (See Plate VII.)

The corresponding stresses on the guy and the equivalent load on the boom are shown in Figures 7A, B, and C and are listed in the following table for a one-ton load at a fall angle of 120°.

<i>Guy position</i>	<i>Guy tension</i> (tons)	<i>Equivalent load</i> <i>on boom</i> (tons)
A-----	4.4	4.8
B-----	2.9	2.9
C-----	2.6	2.5

From the above it should be evident that when the boom angles outboard from its heel, the guy should be placed abreast the heel or as much farther back as it is possible to go without permitting the boom to jackknife.

Burton Boom

The infrequent failure of the burton gear can now easily be explained in the light of the previous discussion. The boom always angles outboard from its heel. In fact, it is often so far outboard that the angle between the fall and the boom in plan view is less than that between the boom and the guy, which is normally placed well behind the heel of the boom. Because the burton boom is usually lower than the up-and-down boom, the stress on the guy is further decreased by the fact that the guy of the burton boom is more nearly horizontal than is the offshore guy. Taken together these factors all combine to keep the stresses on the burton boom at a minimum.

JACKKNIFING

It was pointed out above that when the up-and-down boom angles outboard from its heel, the guy (and the preventer) will have the least tension on it when it is as far back of the heel as possible but not so far back as to allow the boom to jackknife. The question is, how far is "as possible"?

PLATE VII.—Showing changes in tension on guy and equivalent load on swinging boom with changes in position of guy. Boom angled out-board. Fall angle 120° .

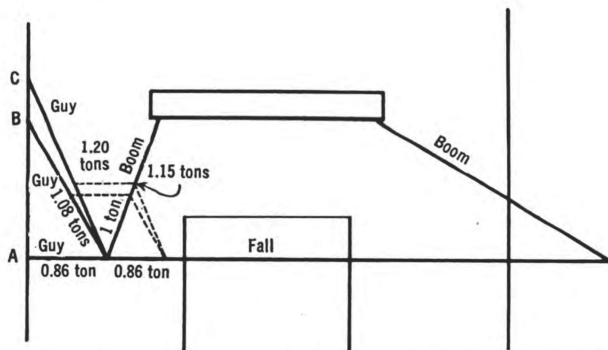


FIGURE 7.—Plan, three different positions of guy showing horizontal pull on guy and horizontal thrust on boom. Fall angle 120° .

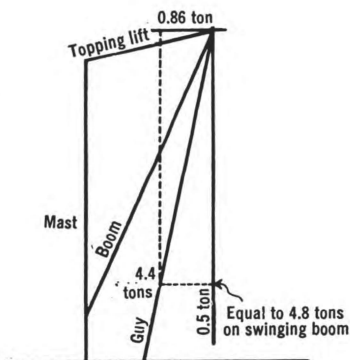


FIGURE 7A.—Tension on guy and equivalent load on swinging boom with guy at A in plan.

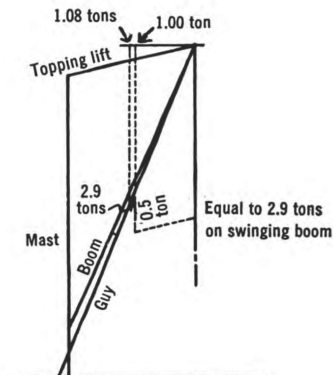
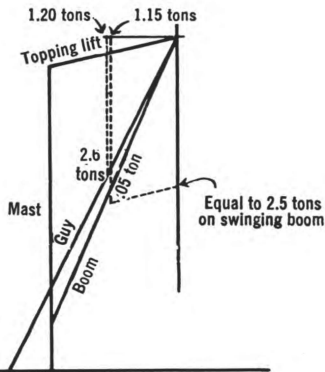


FIGURE 7B.—Tension on guy and equivalent load on swinging boom with guy at B in plan.



**FIGURE 7C.—Tension on
guy and equivalent load
on swinging boom with
guy at C in plan.**

There is no way, other than calculation or experiment, to tell whether a particular setup will cause the boom to jackknife with a particular fall angle. For example, with the guy at C in Figure 7, a load at a fall angle of 120° is perfectly safe, but over 150° the boom would probably jackknife.

For safety, it is desirable to place the guy in a position which will hold the boom down, no matter how much it is tightlined, without securing it so far out toward the head of the boom as to place an unnecessarily high stress on the gear. This condition is met when either the guy or the preventer is secured to a pad eye located so that when one sights from the pad eye to the head of the burton boom the latter appears just beneath the up-and-down boom.

Again, using the examples in Figure 7, sighting from the pad eye on deck at C, the head of the burton boom would appear above the heel of the up-and-down boom, indicating that the latter can jackknife. On the other hand, sighting from the pad eye on deck at B, the head of the burton boom would appear a couple of feet below the up-and-down boom. Unless the burton boom itself jackknifed high enough to appear above the up-and-down boom, the latter could not jackknife even by tightlining the empty hook.

Jackknifing the Burton Boom

Once the up-and-down boom starts to jackknife, it is practically impossible to drop the load fast enough to stop it. Since the burton boom is the lower of the two, it does not act in the same manner but is raised by the fall. As soon as the winch driver stops heaving, the boom stops rising. For this reason, it is not so important that the burton boom be held down by the guy.

The same method of sighting is used for the burton boom as for the up-and-down boom. Sighting from the pad eye to which the outboard guy of the burton boom is secured, the head of the up-and-down boom will probably appear either above the burton boom or below it.

If the head of the up-and-down boom appears below the burton boom, the latter cannot rise at all.

If the head of the up-and-down boom appears above the burton boom, the latter can rise until it reaches the line of sight. It cannot be raised above this line even by tightlining an empty hook. This is the usual condition in actual practice. It causes no harm as long as the amount of rise is not enough to cause the up-and-down boom to jackknife.

If the head of the up-and-down boom should appear behind the king post which supports the burton boom, the latter can be raised all the way and will, by changing the line of sight, probably cause the up-and-down boom to jackknife also. This situation is often found at the

No. 4 forward gear on Victories and on any set of gear where the heels of the booms are close to the rail.

In such cases, particularly at No. 2 aft and No. 3 forward on many C-4's, it is suggested that the guy be left well back of the heel. To put the guy where it would prevent topping the boom, would mean that it would be so nearly parallel to the boom as to place it under terrific tension. Then, to hold the boom down, place the preventer under the boom and leave it a foot or two slack.

This exception to the rule that preventers must be kept tight is to avoid the chance of the guy becoming slack (as in drying out after having been set up while wet) and throwing all the load on the preventer which, in this position, would probably carry away with a very light load.

Ebel Gear

On many new vessels there is an unusual rig known as the Ebel gear, in which each boom is supported by two topping lifts. The outboard topping lift reeves through a block and continues down to the deck to serve as a guy. The result of tightlining a load on this gear is to cause the burton boom, or in some cases the up-and-down boom, to top up. No danger is involved as the booms will not fly back. They will stop rising as soon as the winch driver stops heaving in.

With this gear, it is important that no attempt be made to hold the booms down with preventers, as to do so would subject the gear to excessive stress such as occurs when the usual type of gear is tight-lined. As designed, the Ebel gear can burton the full 5 or 10 tons for which it is rated and, as long as the booms are free to top up, the gear will not be overloaded no matter how high the load is raised. This is the only burtoning gear of which we know that has this safety characteristic.

PREVENTERS

Preventers are poor substitutes for guys that are not strong enough. First, they cannot equally share the load with the guy. The preventer is usually a single heavy wire while the guy has a manila purchase. If the preventer and the guy have an equal tension under a light load, the guy stretches much more than the preventer under heavier loads so that the latter has to take most of the increase.

Second, rarely are fastenings available to secure the guy and the preventer close together on the deck or rail. We have seen that changing the position of the guy, changes the tension on it. If the guy is in one place and the preventer in another, the tension on the two will not be equal under all degrees of tension because the stress on one will increase more rapidly than on the other.

Third, the preventer is not usually included in the design and therefore gets little attention. Often it is a worn out fall, to start with, suitable provisions for properly securing it may be lacking, and it may be permitted to get in very poor shape.

While there have been few cases in which either the guy or preventer parted and the other held, it is undoubtedly true that the proper use of preventers has saved many a weak guy. It is therefore false economy for the stevedore to neglect to set them up properly. The following suggestions are offered:

1. Secure the preventer as close to the guy as available fastenings permit.

2. When the two cannot be nearly parallel, it is preferable that the guy be in the position of greater stress. That is, more nearly in line with the fall under most conditions.

3. Under light load (which is better produced by lifting a pontoon or beam on the hook than by hooking into a pad eye and using the winch power directly), the guy should be adjusted until there is a little more tension on it than on the preventer. Under a heavy load the guy will stretch and let the preventer have its share.

4. Neither the preventer nor the guy should have real slack in it as it is almost a certainty that if one fails, the other will part when it fetches up with a jerk after the slack is taken out, and there will be two pieces of gear flying around instead of only one. The preventer is useful only in keeping the guy from parting, not in holding the boom after the guy parts. (A few vessels have heavy preventers which are intended to carry the guy load, and very light guys which are intended only for trimming the booms. So little additional strength is provided by these guys that they may better be left slack.)

5. Since the manila guy purchase shrinks when wet and stretches when dry, it must be checked from time to time during the job.

SUMMARY OF SUGGESTED SAFE PRACTICES IN RIGGING AND USING CARGO HANDLING GEAR

1. Since the load on a topping lift increases as a boom is lowered, longshoremen should be instructed to take sufficient turns while the boom is high to insure having control of it when it reaches a low position (p. 4).

2. Where there is a choice between a long and a short mast, with corresponding high and low topping lift blocks, in relation to the length of the boom, it will usually be safer to burton heavier loads, such as lift trucks, with the gear on the longer mast (p. 4).

3. Particular care should be taken to avoid overloading or putting shock loads on the gear when the boom is at a low angle (p. 5).

4. Care should be taken to avoid letting a loaded boom rest against a stay, shroud, or other fixed object as the resultant bending may cause the boom to fail (p. 6).

5. Booms should be inspected before starting work, and any that are visibly bent should be recognized as having been weakened (p. 5).

6. Before applying power to a guy, be sure that the gooseneck is free to turn by heaving on the guy by hand (p. 6).

7. In using the jumbo, avoid slewing the boom at high angles by slewing the boom first and then topping to the desired position in loading and by lowering it before swinging in discharging (p. 6).

8. Guy winch drivers, or men handling the guys on a jumbo boom, should both have the signalman in clear sight at all times and should be instructed to stop heaving if at any time the stress on the hauling part appears to be excessive (p. 6).

9. A check should be made with the mate before making a heavy lift with the jumbo to find out whether auxiliary stays need to be set up (p. 7).

10. To keep tension on the falls as low as possible in burtoning and so avoid excessive tension in the guys, the following suggestions are offered (pp. 8, 10) :

a. Use slings as short as practical.

b. Keep the hook as close to the junction of the falls as possible. Chain for additional weight should be hung in a bight beside the hook rather than used to connect the hook with the junction of the falls.

c. Keep the loads as close to the rail, deck, and coaming as possible.

d. Avoid severe tightlining of even very light loads as a difference of only a foot or two in the height of the load may increase the stress tremendously.

11. The closer the heads of the booms to each other and the higher they are, the less will be the tension on the fall and hence on the guys for a given height of the junction of the falls (p. 14).

12. Rules for placing guys for minimum stress :

a. When the up-and-down boom angles inboard from its heel, place the guy at right angles to the boom as seen when looking up from on deck (p. 14).

b. When the boom is fore and aft, the stress on the guy will be least when it is at right angles to the boom. With a spindly boom and a heavy guy, the guy should be abreast the heel of the boom. The tension on it will be increased slightly but the compression on the boom will be reduced (p. 17).

c. When the boom angles outboard from its heel, place the guy abreast the heel or as much behind it as possible without permitting the boom to jackknife (p. 17).

13. Jackknifing:

- a. The up-and-down boom cannot jackknife if either the guy or the preventer is abreast the heel of the boom and no higher than the heel (p. 19).
- b. The means of controlling jackknifing of the burton boom are explained on (p. 19).

14. Preventers should be secured as close to the guy as available pad eyes permit (p. 21).

15. Under light load, the guy should be adjusted so that it has a little more tension on it than does the preventer. It is safer to apply this load by lifting a weight than by shackling the fall to the deck and heaving with the winch (p. 21).



Compliance with the suggestions contained in this bulletin should be helpful in preventing gear failures. Its use as an instructional handbook for stevedores is recommended as a means of preventing personal injury and property damage.

